The Anniversary Tribute of PICMET: 1989–2018

D Cetindamar, T Lammers, D Kocaoglu, Y Zhang

IEEE Transactions on Engineering Management

Abstract

The Portland International Center for Management of Engineering and Technology (PICMET) was established in 1989. It has since become a leading organization in the field of engineering and technology management, worldwide. PICMET provides a strong platform for academics, industry professionals and government representatives to exchange new knowledge derived from both research and implementation of technology management. To celebrate its 30-year journey, this paper examines 20 conferences organized by PICMET covering 6,601 accepted papers. It shows the trends in technology management research and implementation through topics, authors, journals and countries. In addition, the paper delves into the past ten years (2009-2018) to carry out an in-depth bibliometric analysis of the citations of more than 3,000 papers. This detailed analysis focuses on the citation of PICMET authors to shed light on the interdisciplinary nature of the engineering and technology management field. The paper ends with some observations and suggestions for further studies.

Keywords: PICMET, technology management, bibliometrics

1. Introduction

The Technology Management (TM) discipline has a history of almost 70 years, taking 1951 as the rough starting date as argued at the special issue of IEEE Transactions on Engineering Management in 2004 (Allen, 2004). TM has become a self-sustained discipline in the last 30 years with proliferation of education programs, a growing number of journals dedicated to the field (such as *Technological Forecasting and Social Change*) and the emergence of specialized professional organizations, in particular PICMET (Portland International Center for Management of Engineering and Technology) (Roberts, 2004).

Critical self-evaluation is beneficial for a domain area and organization to observe its impact and evolution. The literature is populated with numerous systematic observations that might be considered as "state of the discipline" appraisals for a number of academic disciplines (Sarin et al., 2018). The analysis of a body of knowledge offers many advantages: showing trends in the field, pointing out the main knowledge generators (i.e. key institutions and authors), and highlighting emerging topics in a field (Cetindamar et al., 2009).

This kind of systematic analysis has been adopted in the TM field, too. For example, a recent study presents the findings about knowledge flow patterns among six major Technology and Innovation Management (TIM) journals and the effect on their impact factors during the period of 1999-2013 (Sarin et al., 2018). In general, observations of the state-of-the-art of a discipline are made by using mining or bibliometric techniques on that discipline's domain or for specific journals. There are several examples for TM, too (Cetindamar et al., 2009; Durisin et al., 2010; Gudanowska, 2017). However, extant literature seems to ignore one critical actor that contributes to the development of a specific domain where researchers and practitioners meet and discuss: conferences.

To say it with the words of Sir Francis Bacon "Reading maketh a full man; conference a ready man, and writing an exact man". Conferences have many advantages. Among other things, they offer opportunities for presenting research ideas at experimentation stage in front of experts in the field. They allow exchange of information and experience among conference delegates and they help in formulating problems (King, 1961). Nevertheless, literature offers a few journal articles with bibliometric analysis of conferences (Clausen and Wormell, 2001; Wuehrer and Smejkal, 2013). These studies show how conducting such a research intelligence activity for conferences might be beneficial to understand how they serve a knowledge domain. However, there is one major problem which prevents conducting these studies more frequently: The difficulty of getting access to conference papers and data (Wuehrer and Smejkal, 2012).

This paper takes on this challenge and conducts a bibliometric analysis of the PICMET conferences which have made impressive marks on the research field of TM. There are already three conference papers examining PICMET for different periods: the period of 1997-2003 (Porter et al., 2003), the period of 1997-2008 (Kwakkel et al., 2009), and the period of 2001-11 (Porter et al., 2012). This study follows the tradition and covers the whole period of 1991-2018, representing 20 conferences conducted since PICMET's establishment in 1989. We present our findings regarding authors, institutions and topics covered in PICMET papers like the previous articles have done. Then, we make comparisons with the previous studies to highlight some key changes that show the historical evolution of PICMET. In addition to the traditional analysis, we also present a citation network analysis, based on the references used in PICMET papers, that highlights the body of knowledge brought to the PICMET attendees.

This paper has five sections. After this short introduction, Section-2 positions PICMET within the existing conference/event platforms in the TM domain. Section-3 explains the methodology and gives details on data, followed with the presentation of detailed bibliometric analyses in Section-4. The paper ends with a discussion and concluding remarks in Section-5.

2. Technology Management Platforms

The conference proceedings of PICMET '99 start with the following statement in the preface: "As we move toward the third millennium mankind is experiencing one of the most profound changes in its history. That change is the shift from the material-based society to a knowledge-based society driven by technological know-how. Every aspect of life is being affected by technology, every corner of the world is feeling the impact of rapid technological changes. We are entering a new era whose characteristics are shaped by technological innovations….. When the term "technology" is used in this paper, it is not restricted to the hardware and software combination. Those are seen as the outputs of technology, not the technology itself. Technology refers to the knowledge system that produces the results in the form of those outputs." (Kocaoglu, 1999, p.1).

TM is the development and exploitation of technological capabilities that are changing continuously. TM activities such as selection and exploitation are typically embedded within core business processes: strategy, innovation and operations (Cetindamar et al., 2009). They can be included in any business process, department, or business system level (i.e. project, strategic business unit, corporate) in the firm. For instance, technology selection decisions are made during business strategy and new product development.

The TM discipline dates back to the early-1950s (Allen, 2004), becoming an established discipline in the late 1980s (Cetindamar et al., 2009). In the 21st century, TM has become a 'traditional business subject', according to the International Association to Advance Collegiate Schools of Business (AACSB, 2009). The literature describes the intellectual development of TM as a field, and its trends are continuously published in influential journals (Linton and Thongpapanl, 2004; Thongpapanl, 2012; Cetindamar et al., 2009; Duan, 2011). The core focus of TM has changed significantly over the past decades; from research and development (R&D) to strategic management, and ultimately to Innovation Management (IM) (Drejer, 1997; Horwitch

and Stohr, 2012). Recent works emphasize the overlaps between TM and IM (Meyer-Brotz et al., 2018; Sarin et al., 2018; Shum et al., 2019).

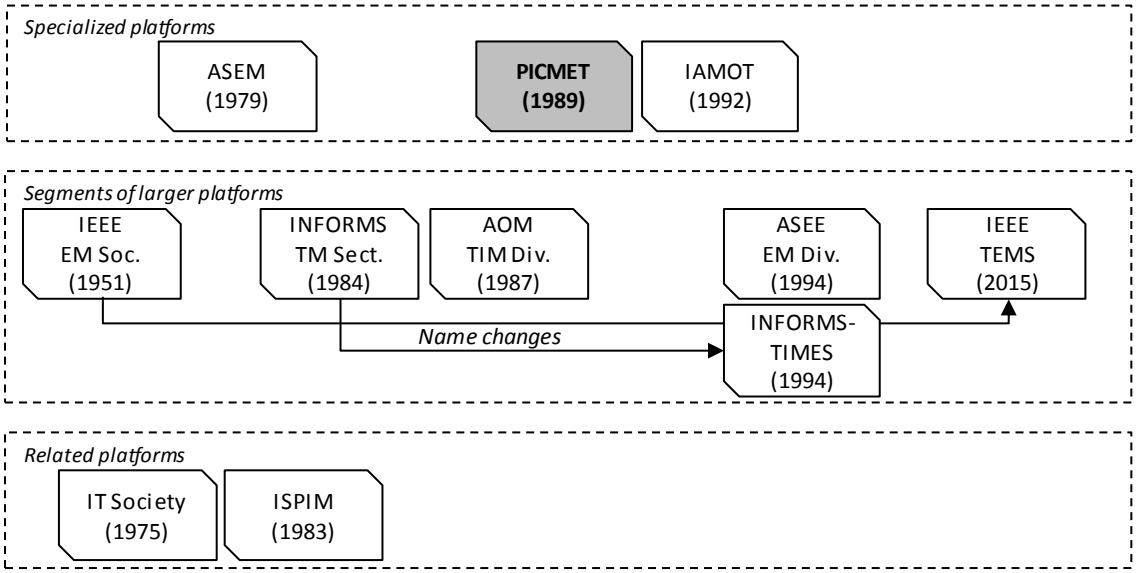
PICMET is positioned in the context of platforms being either an association or a professional organization where academics and practitioners meet and exchange knowledge related to TM. We classify these platforms into three groups as shown in Figure 1. The first group is the core field of specialized platforms directly related to TM with three major players: PICMET, IAMOT (International Association for Management of Technology), and ASEM (American Society for Engineering Management). PICMET and IAMOT have a strong focus on academic work. PICMET describes its goal as dissemination of information on technology management through an international conference. IAMOT encourages not only research, but also education in academic institutions. ASEM is a professional society promoting and advancing the field of Engineering Management (EM) with special focus on management of people and projects in a technological or engineering systems context.

A second group of platforms are divisions or sections organized within larger platforms. The key members of this group are INFORMS – TIMES (The Institute for Operations Research and the Management Sciences – Technology, Innovation Management and Entrepreneurship Section), AOM - TIM (Academy of Management - The Technology and Innovation Management) Division, ASEE - EM (American Society for Engineering Education - Engineering Management) Division and IEEE – TEMS (The Institute of Electrical and Electronics Engineers – Technology and Engineering Management Society). The Institute of Management Sciences established its College on Engineering Management (COLEM) in 1976. It was combined with COLRAD (College on Research and Development) and COLIME (College on Innovation Management and Entrepreneurship) to become the TM Section of INFORMS. The TM Section then changed its name to TIMES in 1994. Its goal is to encourage discussion and interaction among individuals having an interest in technology management research. Topics of interest to the TIMES audience include R&D Management, Technology and Organizational Change, Technology and Strategy, Technology and Resources, Product Development, and Entrepreneurship. AOM - TIM has a more limited focus. Its goal is to bring together scholars interested in innovation, research and development, and the management of technology-based organizations. AOM is a large organization in the USA, and its TIM division with 3,000 members is one of the larger Divisions. IEEE is a professional association for electrical and electronic engineering. It established the Engineering Management Society (EMS) in 1950s. EMS became TEMS in 2015. IEEE-TEMS

has been influential in TM field through its flagship journal *IEEE Transactions on TEM* since its launch in 1954.

The final category of platforms consists of related platforms that cover themes overlapping with specialized platforms. We consider two major ones as the ISPIM (International Society for Professional Innovation Management) and the TT (Technology Transfer) Society. ISPIM is an association of members from research, industry, consulting and the public sector, all sharing a passion for innovation management. It started in Norway and became a global organization. TT Society is an international forum for the exchange of ideas that enhance and build an understanding of the practice of technology transfer. TT Society has been organizing conferences and publishing a journal titled *Journal of Technology Transfer*.

Figure 1. Platforms of Technology Management and Engineering Management



We focus on PICMET in this study. Its 30th anniversary in 2019 gives us a unique opportunity to observe the evolution of the platform from the perspective of TM, the academic discipline it represents. PICMET has more reliable and consistent data in Scopus compared to other platforms. We were also interested in the other specialized platform IAMOT, but could not find sufficient data to include them in this study. Many IAMOT conferences are not available in Scopus. Some of its conferences do not have published proceedings either, and its official website does not refer to conferences after 2015. For IEEE TEMS, several conferences (such as 2012 and 2014) are missing. In addition, there are irregularities in the number of papers for the years

documented. For example, Scopus database shows that 3,464 papers are shown for 2007, and 19 for 2013.

3. Methodology

3.1. Method

Bibliometrics is a research field of information and library sciences that studies the bibliographic data with quantitative methods (Broadus, 1987). Due to the development of computers and internet (Bar-Ilan, 2008), bibliometrics has become a practical approach to analyze scholarly research because it provides a comprehensive overview of the leading trends occurring in the academic community (Gaviria-Marin et al. 2018).

In the literature, there are bibliometric studies for a wide range of purposes including the analysis of a research field, journal, country and university. Research fields that have been widely studied through bibliometric approaches are management (Podsakoff et al. 2008), economics (Coupe, 2003), innovation (Fagerberg et al. 2012), and entrepreneurship (Landström et al. 2012). Some examples of journals that have already developed a bibliometric analysis of its publications are *Technovation* (García-Merino et al. 2006), *Journal of Product Innovation Management* (Biemans et al. 2007; Durisin et al. 2010), and *the Journal of Knowledge Management* (Gaviria-Marin et al. 2018).

Focusing on technology management, Linton and Thongpapanl (2004), Ball and Rigby (2006) and Thongpapanl (2012), presented a ranking of journals. Linton (2004) developed a ranking of business schools. Thieme (2007) and Yang and Tao (2012) studied the leading authors and universities in innovation management. There are some other articles that have focused on other related issues including the publications of China and India in technological innovation (Chatterjee and Sahasranamam, 2018) and research connected to strategic alliances and innovation (Di Guardo and Harrigan, 2012).

In order to develop a bibliometric analysis, it is important to define and select the bibliometric indicators that will explain the results (Ding et al. 2014). This paper considers the number of publications and citations. The number of publications is used to measure productivity and the most productive actors while the number of citations measure popularity and influence (Meyer-Brotz et al., 2018).

One focus of this work is to present a graphical mapping of the bibliographic data (Cobo et al. 2011). To do so, we use the visualization of similarities (VOS) viewer software (Van Eck and Waltman, 2010). VOS viewer is a computer software that collects the bibliographic data and builds maps according to different bibliometric techniques including co-citation, bibliographic coupling and co-occurrence of keywords (Kessler, 1963; Small, 1973). Graphical maps with co-citations (Cetindamar et al., 2019) measure the most cited actors (size of the circles) and those that receive most frequent citations from the same sources. Graphs with bibliographic coupling analyze the actors with the highest number of publications (size of the circles) and those who cite most frequently the same sources (Van Eck and Waltman, 2010). Maps with co-occurrence of keywords measure the most popular keywords (size of the circles) and those keywords that appear most frequently in the same papers (Pilkington, 2014).

3.2 Data

We use two sets of data. One is received from PICMET and the other is based on the Scopus database. The reason for not relying solely on Scopus for the whole bibliometric analysis is the 30% discrepancy in the Scopus database compared with the PICMET database on conference papers as shown in Table 1. However, the difference is less than 7% in the last 10 years, thus when we conduct citation analysis of PICMET papers, we utilize the Scopus database in the 2009-2018 time period for a practical reason: the citation analysis would not be easy to do with the PICMET database that does not include reference lists for each paper unless it is done manually.

Table 1. PICMET conference papers according to PICMET and Scopus data sources, 1991-2018

Year	91	97	99	01*	03	04	05	06	07	08	09	10	11	12	13	14	15	16**	17	18	Total
PICMET	270	472	375	396	277	206	316	265	314	256	307	312	371	381	325	428	328	381	295	326	**6601**
Scopus	0	206	0	266	52	0	56	276	340	302	363	317	341	341	303	428	279	0	591	256	**4717**

* Even though there was no conference in 2002, the Scopus database lists 192 papers.
** All 2016 papers appear as 2017 in the Scopus database.

The search process uses different keywords of PICMET including the full and abbreviated names. There were different entries for PICMET's official name, such as Portland International

Conference "on"/"for" Management of Engineering and Technology, and Portland International Conference on Management "for"/"of" Engineering "and"/"&" Technology.

4. Data Analysis

4.1. Trends in number of papers, authors, and institutions

PICMET organized 20 conferences since its inception. Altogether, 6,601 papers were accepted for inclusion in PICMET conferences as shown in Table 1. The number of papers was consistently above 300 except for the years 1991, 2003, 2004, 2006, 2008 and 2007. The highest numbers were 471 in the 1997 conference and 428 in the 2014 conference.

Tables 2-a and 2-b present the most productive countries, institutions and authors contributing to PICMET, defined by the number of papers included in PICMET conferences. The analysis of countries represents the author affiliations at the time of publication in PICMET. While the USA made up one fourth of the papers in the period of 1997-08, this ratio dropped to 18% in the 2009-2018 period. An interesting increase is seen in the number of papers by Taiwan from 92 in the 1997-08 period to 458 in the last decade. Three Asian countries, China, Japan, and Taiwan make up 40% of all papers during 2009-2018. Although Japan increased its ratio from 6% to 14% of all papers presented in PICMET, its ranking dropped to the third position in the period of 2009-2018. The UK almost kept its ratio of contribution to PICMET in the range of 3-4% of all papers. Turkey lost its fourth contributor position, but still made the top 10 list. The only country that fell from the top 10 most productive countries list was Finland, which was replaced by Germany in the second period.

Table 2-a. The most productive countries, institutions, and authors, in 1997-2008

1997-2008					
Country	**# papers**	**Institution**	**# papers**	**Author**	**# papers**
USA	764	Portland State Univ., USA	109	Kocaoglu DF	24
Japan	167	ETRI*, South Korea	51	Daim TU	23
UK	132	U of Pretoria, South Africa and U of Sao Paulo, Brazil	40	Probert DR	21
Turkey	125	U of Tokyo, Japan	34	Wilemon DL	19

South Korea	121	Cambridge Univ., UK	33	Niwa K	17
China	117	Istanbul Tech. Univ., Turkey	30	Carayannis EG	16
Brazil	101	Stevens Inst. Of Technol., USA & Zhejiang Univ., China	26	Jaakkola H	16
Taiwan	92	Rensselaer Polytech. Inst., USA	24	Anderson TR	16
South Africa	82	Tampere U of Technol., Finland and Swiss Fed. Inst. of Technol., Switzerland	23	Shenhar AJ	14
Finland	65	Texas U, USA	21	Pretorius L	13

Table 2-b. The most productive countries, institutions, and authors, in 2009-2018

2009-2018					
Country	**# papers**	**Institution**	**# papers**	**Author**	**# papers**
USA	583	Portland State Univ. USA	223	Daim T	54
Taiwan	458	U of Pretoria, South Africa	127	Schuh G	45
Japan	454	U of Tokyo, Japan	84	Sakata I	42
China	347	U of Sao Paulo, Brazil	77	Su HN	36
South Africa	188	Tokyo Institute of Technology, Japan	75	Kajikawa Y	30
Germany	163	Japan Adv Inst Sci Tech, Japan	74	Kocaoglu DF	27
Brazil	150	China Research Inst for Sci Pop, China	51	Pretorius L	27
South Korea	139	Tampere U of Technology, Finland	46	Shirahada K	22
UK	83	Beijing Institute of Technology, China	46	Ikawa Y	21
Turkey	72	RWTH Aachen U, Germany	41	Miyazaki K	21

* ETRI (Electronics and Telecommunications Research Institute)

The USA is the country with the highest number of papers and the strongest bibliographic connections for PICMET. This is not surprising given both the country affiliation of PICMET itself and the country's size. Other big contributing countries, such as Japan, Germany, China, South Africa and Brazil, are again in line with results for biggest contributing authors and institutions. This was also the case in the previous PICMET analysis (Kwakkel et al., 2009).

The most productive institutions contributing to PICMET (using the same bibliometric indicators) in the 20-year period, 1997-2018, are the conference's home institution, the Portland State University in the USA (232 papers), the University of Pretoria in South Africa (167 papers) and the University of Tokyo in Japan (118 papers). In addition, the RWTH Aachen in Germany and the Tampere University of Technology in Finland have remained among the top productive institutions for PICMET authors since 1997.

With the exception of G. Schuh from Germany and L. Pretorius of University Pretoria in South Africa, all other top 10 authors come from Japan, Taiwan and the USA reflecting PICMET's geographic scope in the Pacific region. Two PICMET authors, DF Kocaoglu, T Daim along with L Pretorius of University of Pretoria, are in the top 10 authors-list in both ten-year periods, 1997-2008 and 2009-2018.

In addition to the number of papers, we considered several other bibliometric indicators such as the number of citations and the number of cites per paper to calibrate the quality of the authors' contribution to TM field. The Scopus database was used, for this purpose, to draw the data presented in Table 3. The top three authors based on the total citations received for their PICMET conference papers are G Schuh, T Daim and DF Kocaoglu, who received 2.51, 1.81 and 1.67 citations per paper in PICMET, respectively. These three authors' papers have also attracted the highest citations according to the Web of Science database.

Table 3. Top 10 PICMET authors, 2009-2018

Rank	Author	Institution	Country	Papers (P)	Citations (C)	Citations per paper (C/P)
1	Daim T	Portland State U	USA	54	98	1.81
2	Schuh G	RWTH Aachen U	Germany	45	113	2.51
3	Sakata I	U Tokyo	Japan	42	24	0.57
4	Su HN	Nat Chung Hsing U	Taiwan	36	27	0.75
5	Kajikawa Y	U Tokyo	Japan	30	32	1.07
6	Kocaoglu DF	Portland State U	USA	27	45	1.67
7	Pretorius L	U Pretoria	South Africa	27	29	1.07
8	Shirahada K	Japan Adv Inst Sci Tech	Japan	22	17	0.77
9	Ikawa Y	Japan Adv Inst Sci Tech	Japan	21	32	1.52
10	Miyazaki K	Tokyo Inst Tech	Japan	21	29	1.38

* Citations received by these authors based on their publications in journals according to the Web of Science database.

Source: Scopus

4.2. Trends in categories and keywords

From 2003 onwards, authors selected a primary and a secondary subject category most relevant to the scope of their contribution from a pre-defined list provided by PICMET as part of the submission process. The selectable categories were about the research area (e. g. cyber security, supply chain management, etc.) as well as the industry or sector as application area (e. g. automotive industry, government, etc.). Throughout the years, new categories were added to the list to reflect emerging topics. Overall, there are 82 categories now – 62 research areas and 20

application areas. Table 4-a presents the trends in categories for industries and sectors, and 4-b in research areas. The categories are ranked by the number of selections in the 2003-2018 time period. The tables contain data for both primary and secondary categories as they can be used interchangeably by the authors.

Table 4-a. Evolution of categories – industries and sectors: 2003-2018

Industries and Sectors	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**TOTAL**
Sector: Energy	6	7	10	4	2	7	4	7	37	18	13	19	8	13	14	13	182
Industry: Semiconductor	39	46	47	3	2	3	5	9	3	6	4	5	0	2	1	2	177
Industry: Telecommunication	25	23	21	17	17	6	5	9	6	12	9	9	5	6	2	1	173
Sector: Service	1	1	3	9	16	11	9	12	8	12	13	24	9	10	5	5	148
Sector: Health	10	17	16	2	4	5	9	5	6	7	10	14	4	15	12	10	146
Industry: Transportation	16	16	21	2	6	3	3	5	6	7	2	4	7	7	6	7	118
Industry: Wireless Technology	30	18	32	3	1	2	1	0	0	4	3	2	0	0	0	0	96
Industry: Nanotechnology	23	19	26	2	6	0	2	2	2	4	2	1	1	1	3	1	95
Industry: Biotechnology	3	2	2	4	5	4	4	1	6	9	9	9	2	8	4	8	80
Sector: Education	0	0	0	0	0	0	0	0	0	7	10	9	11	13	10	7	67
Sector: Government	0	0	2	3	9	5	1	7	11	2	5	6	4	1	4	2	62
Industry: Information Technology	0	0	0	0	0	0	0	0	0	12	7	10	6	9	6	7	57
Industry: Computer	0	0	0	0	0	10	6	7	13	10	1	1	2	0	1	2	53
Industry: Microprocessors	10	9	20	0	1	0	1	0	0	0	1	0	0	0	0	0	42
Industry: Electronics	2	0	4	2	5	2	7	1	2	3	3	3	2	2	0	1	39
Sector: Defense	2	1	4	1	1	6	2	3	1	1	1	1	6	1	2	1	34
Sector: Financial	5	2	3	0	0	1	0	0	1	2	3	2	3	4	5	3	34
TOTAL	172	161	211	52	75	65	59	68	102	116	96	119	70	92	75	70	

Interesting observations can be made about the evolution of application areas. The second-most relevant application area overall is the semiconductor industry, but more than 75% of its selections have appeared in the first three years of the analyzed timeframe, and declined significantly after that. A similar trend has occurred for the third most relevant category overall – the telecommunications industry, where more than 63% of selections happened in the first five years. Wireless technology, nanotechnology and microprocessors have also experienced a decline. On the other hand, the energy, service and education sectors have gained in relevance for PICMET. Additionally, some of the categories, namely the Aerospace, Automotive and Robotics industries have never been selected by the authors. Overall, a shift away from specific IT-related industries to broader application areas can be observed.

Table 4-b. Evolution of categories – research areas: 2003-2018

Research Areas	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	TOTAL
Innovation Management	8	5	6	46	52	44	50	58	73	68	69	77	62	77	62	67	824
Strategic Management of Technology	4	3	7	23	29	29	34	30	45	36	24	25	20	29	15	25	378
R&D Management	6	3	10	23	26	29	26	28	30	20	33	33	22	27	24	24	364
Competitiveness	58	29	50	13	15	9	20	20	17	15	13	17	16	12	8	11	323
Collaborations	31	10	45	18	12	8	21	17	15	19	19	31	20	26	12	16	320
New Product Development	9	6	7	25	27	25	19	20	17	22	18	24	25	35	16	18	313
Decision Making	10	6	4	18	11	18	23	20	28	29	32	21	31	17	19	23	310
Science and Technology Policy	14	19	13	14	20	17	10	16	31	23	20	23	18	25	16	21	300
Project/Program Management	6	0	4	20	30	30	22	21	25	21	18	17	14	17	15	15	275
Knowledge Management	0	0	0	0	0	18	24	31	21	37	25	33	17	26	23	14	269
Information Management	7	4	5	15	40	16	18	17	17	15	19	10	7	16	10	14	230
Other Topics	0	0	0	20	28	20	25	14	22	15	18	16	14	15	14	9	230
Emerging Technologies	15	19	15	7	14	1	8	13	10	31	12	7	19	20	20	18	229
Technology Assessment and Evaluation	14	6	12	14	13	16	12	13	21	18	11	16	16	15	9	11	217
Entrepreneurship/Intrapreneurship	8	2	8	8	9	9	11	10	8	5	6	15	14	20	21	43	197
Manufacturing Management	11	6	14	4	9	7	10	13	12	10	8	17	11	10	10	9	161
Cultural Issues	16	18	24	7	4	8	12	5	12	10	3	8	8	7	3	6	151
Technology Management Framework	0	0	0	12	7	13	20	14	13	9	8	15	10	13	9	5	148
Technology Adoption	2	3	1	12	12	4	8	20	11	11	6	14	12	6	12	8	142
Global Issues	13	8	24	9	5	6	10	7	6	7	3	9	9	11	4	4	135
Intellectual Property	0	0	0	0	0	0	0	0	0	14	14	28	15	30	18	16	135
Technology Forecasting	0	0	0	5	7	5	8	11	16	17	17	8	16	10	7	7	134
Productivity Management	9	3	9	4	10	1	10	10	10	7	9	9	10	6	8	9	124
Technology Transfer	0	0	0	15	5	6	17	10	9	11	10	16	3	11	4	4	121
Environmental Issues	4	4	4	5	4	3	8	9	10	13	5	14	8	15	1	10	117
Supply Chain Management	5	3	6	12	9	12	9	6	5	6	9	6	9	11	3	4	115
Convergence of Technologies	21	12	19	0	17	0	4	2	5	8	3	4	6	5	3	5	114
Technology Diffusion	0	0	0	5	4	8	10	7	12	13	9	13	10	7	5	7	110
E-Business	6	7	7	6	13	4	8	9	7	3	5	8	4	6	10	3	106
Technology Roadmapping	0	0	0	4	5	6	12	10	14	8	8	6	11	8	5	7	104
Commercialization of Technology	0	0	0	0	0	0	1	1	0	22	10	10	15	17	5	7	88
Technology Management Education	0	0	0	11	10	13	7	5	5	6	3	7	6	6	4	4	87
Disruptive Technologies	7	8	13	5	1	2	1	4	2	2	7	6	5	4	10	8	85
Technology Based Organizations	12	15	21	3	3	2	2	6	5	5	2	4	1	1	0	2	84
Enterprise Management	0	0	0	0	0	0	0	0	0	0	12	15	14	11	8	18	78
Resource Management	4	1	1	2	6	5	1	4	13	4	7	4	2	7	4	3	68
Technical Workforce	5	0	2	4	10	5	5	4	6	3	3	4	4	5	3	1	64
Technology Planning	0	0	0	7	2	4	4	8	7	6	4	3	11	0	4	3	63
Software Process Management	1	0	1	8	8	6	5	5	5	7	4	5	2	2	0	3	62
Technological Changes	0	0	3	4	2	2	3	5	7	5	6	8	4	0	5	6	60
Technology Marketing	0	0	0	4	5	4	4	4	4	10	4	9	3	2	2	4	59
Outsourcing	8	0	7	10	4	3	4	2	2	3	3	5	2	1	2	0	56
Sustainability	0	0	0	0	0	0	0	0	0	0	12	12	6	17	4	4	55
Science and Technology Communication	0	0	0	0	0	0	0	0	0	0	0	15	9	6	13	10	53

Technology Acquisition	2	1	0	7	3	3	2	6	3	2	5	8	4	2	1	4	53
Ethical Issues	15	8	10	0	0	1	0	0	4	2	1	1	2	5	1	1	51
New Venture Development	0	0	1	4	3	3	4	3	6	0	1	4	4	3	3	9	48
Radical Innovations	4	4	6	0	4	5	4	2	3	3	3	1	1	0	3	3	46
Quality Management	0	0	0	0	0	0	0	0	0	7	6	5	9	6	5	4	42
Communication Technologies	0	0	0	0	0	0	0	0	0	0	12	9	4	5	6	1	37
Social Innovation	0	0	0	0	0	0	0	0	0	0	0	0	0	18	3	10	31
Leadership	0	0	0	0	0	0	0	0	0	4	5	4	4	3	4	3	27
Virtual Enterprises	0	0	0	1	4	1	3	3	2	0	2	2	1	0	0	1	20
Social Media	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	4	12
Artificial Intelligence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	3	11
Internet of Things (IoT)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	7	10
System Design	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	2	8
Cyber Security	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	5
Triple Bottom Line	0	0	0	0	0	0	0	0	0	0	0	1	2	0	1	1	5
Conservation	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	4
Resilience of Systems	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	4
Reliability	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1

TOTAL	335	213	359	454	530	451	544	537	618	627	584	700	586	670	509	563

Looking at the evolution of research areas in Table 4-b, Innovation Management and Strategic Management of Technology emerge as most frequently selected categories, and, after an initial ramp-up period they remain rather stable. Following its introduction in 2012, Intellectual Property has established itself as a highly relevant area. The same can be said for Knowledge Management and – to a lesser extent – for Enterprise Management, and Sustainability. Communication-related aspects (such as science and technology communication and communication technologies) have gained relevance in the last few years. Some recent additions to the portfolio of selected categories relate to specific digital technologies (Internet of Things) and the impacts of digital disruption (Cyber Security) representing contemporary areas of research.

Up to now, we have analyzed the primary and secondary categories selected by the authors during the submission process. There are also studies that focus on keyword search in the literature. For example, Cunningham and Kwall (2011) use Scopus database for technology and engineering management, and Meyer-Brotz et al.'s (2018) study derives key technology and innovation themes from Web of Science database. The former study concludes with a list of key 35 keywords. The latter study identifies the top six keywords as "Transitions", "Foresight",

"Innovation Capabilities", "Leadership", "IT", and "KM", which, by and large, resonate with the top 10 PICMET categories.

Inspired with the above-mentioned studies, we carried out another analysis on keywords author-selected keywords by utilizing the PICMET papers available in the Scopus database. Table 5 shows the most frequently used keywords in PICMET publications for the years 2009-2013 and 2014-2018 respectively.

Table 5. Occurrence of keywords: Global and temporal evolution, 2009-18

	2009-20013		2014-2018		TOTAL	
Rank	**Keyword**	**Number**	**Keyword**	**Number**	**Keyword**	**Number**
1	Technology	986	Economics	241	Technology	1031
2	Industrial Management	931	Patents and Inventions	165	Industrial Management	997
3	Industry	395	Commerce	154	Economics	609
4	Economics	368	Competition	140	Industry	395
5	Innovation	248	Innovation	139	Innovation	387
6	Research	241	Surveys	97	Competition	334
7	Competition	194	Engineering	93	Patents and Inventions	309
8	Patents and Inventions	144	Manufacture	83	Commerce	266
9	Information Technology	117	Decision Making	82	Research	241
10	Commerce	112	Investments	70	Surveys	200
11	Surveys	103	Industrial Management	66	Investments	165
12	Investments	95	Product Development	64	Manufacture	160
13	Product Development	89	Competitive Advantage	60	Decision Making	157
14	Societies and Institutions	84	Sales	59	Product Development	153
15	Literature Reviews	78	Literature Reviews	57	Literature Reviews	135
16	Manufacture	77	Science and Technology	56	Societies and Institutions	135
17	Knowledge Management	76	Technology Transfer	56	Technology Transfer	132
18	Technology Transfer	76	Education	55	Sales	129
19	Decision Making	75	Technology Managements	55	Technology Managements	128
20	Technological Forecasting	75	Developing Countries	51	Knowledge Management	127

Source: Scopus

Many of the keywords used in the last 10 years, such as "Economics", "Competition", "Innovation", "Patents" and "Inventions" continue to be used, but there are some other noteworthy developments. The keywords "Industrial Management" and "Technology" are used

less frequently. On the other hand, “Decision-Making” and “Surveys” now receive more attention as research methods. Also “Emerging Technologies” has started to appear frequently as a keyword in PICMET publications in the last five years.

Comparing the years 2014-18 with the previous five-year period reveals some noteworthy changes. Even though the keywords “Technology” and “Innovation” remain in the top 10, the most popular keywords now also include “Economics”, “Industry”, “Competition” and “Patents”. For the first time, the top keyword mentioned in PICMET papers has become “Economics” replacing “Technology”, which had been on top of the list since 1991.

“IT” holds a core place within TIM studies as identified through the growing proportion of articles published in general (Meyer-Brötz et al., 2018) and in the “Research Technology Management Journal” specifically (Shum et al., 2019). However, “IT” does not appear in the top 30 keywords used by PICMET authors. This might be due to a shift of authors in this field to other conferences and outlets that might be more specific to the IT domain.

4.3. Co-citation analysis of PICMET publications

4.3.1 Analysis of papers citing PICMET publications

PICMET papers are being cited in articles published in academic journals on a variety of topics. Overall, 2,494 journal articles cited PICMET papers that were published in the PICMET proceedings during the entire period of 1997-2018 according to the Scopus database. Table 6 displays an overview of journals, which contain articles that cite PICMET. The top 17 journals with more than 15 citations of PICMET articles are shown for the timespan available in Scopus (1997-2018). This analysis is done for the first time for PICMET papers since it had not been carried out in the previous two bibliometric analyses (Porter et al., 2003; Kwakkel et al., 2009).

Overall, the thematic orientations of the journals citing PICMET align with PICMET’s focus areas of Engineering Management and Technology Management (e. g. *International Journal of Technology Management, Journal of Engineering and Technology Management*), Manufacturing (e. g. *Journal of Cleaner Production*), and Project Management (e. g. *International Journal of Project Management*).

Table 6. Journals citing PICMET papers (>15 citations)

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	**Total**
Technological Forecasting And Social Change	0	0	0	0	0	1	0	6	1	3	0	2	10	3	5	5	9	6	15	16	11	15	**108**
Sustainability Switzerland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	9	4	23	**40**
International Journal Of Innovation And Technology Management	0	0	0	0	0	0	0	0	0	2	0	0	0	0	4	11	1	1	2	4	13	1	**39**
Journal Of Cleaner Production	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	2	2	5	6	4	11	**34**
Expert Systems With Applications	0	0	0	1	0	0	0	0	0	0	0	0	2	3	4	6	6	1	3	2	0	1	**29**
Scientometrics	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	4	7	1	2	2	9	**27**
International Journal Of Technology Management	0	1	1	2	0	1	0	1	0	1	0	0	3	0	4	3	0	0	3	4	0	2	**26**
International Journal Of Project Management	0	0	0	0	0	0	0	0	1	0	0	0	0	2	3	4	3	2	1	6	2	1	**25**
Renewable And Sustainable Energy Reviews	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	3	4	4	5	4	0	**24**
Espacios	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1	2	6	9	2	**24**
International Journal Of Technology Intelligence And Planning	0	0	0	0	0	0	0	2	2	1	0	4	1	1	3	1	1	1	0	0	0	2	**19**
Journal Of Engineering And Technology Management Jet M	0	0	0	0	0	1	0	0	0	0	0	0	0	0	5	2	2	7	1	0	0	0	**18**
EMJ Engineering Management Journal	0	0	0	0	1	1	1	0	0	0	2	1	0	1	1	2	3	0	0	1	0	4	**18**
Industrial Management And Data Systems	0	0	0	0	0	0	0	0	0	1	0	3	0	0	2	2	2	1	4	0	0	1	**16**
South African Journal Of Industrial Engineering	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	1	1	3	7	**15**
R And D Management	0	0	0	0	0	0	0	1	0	1	1	0	2	1	1	0	2	0	1	3	0	2	**15**
Foresight	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2	1	2	2	1	1	1	0	**15**

In addition to those topics, there is a strong representation of PICMET references in journals addressing sustainability-related issues (e. g. *Sustainability Switzerland, Journal of Cleaner Production,* and *Renewable and Sustainable Energy Reviews*). Citations in these journals have started in more recent years (from 2011 onwards). This indicates an emerging focus of contributions to PICMET in line with the rise of sustainability as a research field and is an example of PICMET's alignment with contemporary issues.

The Journal of *Technological Forecasting and Social Change* has by far the most citations of PICMET papers. Given the strong reputation of the journal (Q1, H Index 86) (Scimago, 2019), it strengthens the academic credibility of PICMET publications.

Table 7 shows the top 15 authors, institutions, countries, and years according to the number of publications citing PICMET papers of the conferences between 1997 and 2018. As mentioned above, this list is derived from the analysis of the 2,494 publication appearing in the Scopus database that cite PICMET papers in their references. The authors who are citing PICMET papers are regular PICMET participants. T Daim is not only the most productive PICMET contributor, but also the author of articles that are citing his and others' papers presented in PICMET. Authors affiliated with Portland State University (PSU) cite PICMET publications the most (111). This is not surprising since PSU is the host institution of PICMET. Authors affiliated with the University of Cambridge have the second highest number of PICMET citations (52). As the University of Cambridge is one of the world's most prestigious research institutions, this can be seen as evidence for the recognition of the high quality of PICMET publications in the academic world.

Authors from the USA cite PICMET articles the most in their other publications. Five of the other countries in the top ten are from Asia, three from Europe and one from South America. On one hand, this reflects PICMET's geographic location in the Pacific area. On the other hand, strong citations from British, German and Spanish authors further confirm PICMET's worldwide reach.

Since 1997 the number of times, PICMET papers have been cited by authors has continuously increased. In fact, there was only one small dip in consecutive years (from 24 in 2004 to 19 in 2005) since 2004. This short-term dip does not take away from the statement that PICMET publications have constantly gained relevance throughout the conference's history.

Table 7. Top 15 authors, institutions, countries, and years according to the number of publications citing PICMET papers in 1997-2018 conferences

1997-2018							
Author	**# papers**	**Institution**	**# papers**	**Country**	**# papers**	**Year**	**# papers**
Daim, T	69	Portland State University	111	USA	460	2018	371

Phaal, R	30	University of Cambridge	52	China	277	2017	319
Probert, D	23	Beijing Institute of Technology	30	UK	237	2016	315
Porter, AL	18	Seoul National University	28	India	146	2015	268
Basoglu, N	17	Georgia Institute of Technology	27	South Korea	144	2014	250
Anderson, TR	15	National Chiao Tung University Taiwan	25	Malaysia	139	2013	210
Farrukh, C	13	Delft University of Technology	24	Taiwan	126	2012	194
Lee, S	13	Universiteit van Pretoria	22	Spain	101	2011	152
Yoon, B	13	Bogaziçi Üniversitesi	21	Germany	91	2010	119
Geum, Y	12	University of Malaya	20	Brazil	89	2009	91
Pretorius, L	11	Zhejiang University	20	Australia	88	2008	42
Amer, M	10	University of Tehran	18	Iran	83	2007	37
Weber, CM	10	University of Technology Sydney	18	Italy	81	2006	33
Hurmelinna-Laukkanen, P	9	Universiti Kebangsaan Malaysia	17	Japan	75	2005	19
Ning, RX	9	Universiti Utara Malaysia	17	Turkey	73	2004	24

Source: Scopus.

4.2.2. Analysis of PICMET Papers citing other publications

Figure 2 depicts, how relevant journals connect to PICMET based on a co-citation analysis of PICMET publications, considering a minimum threshold of 50 citations received and showing the 100 strongest links.

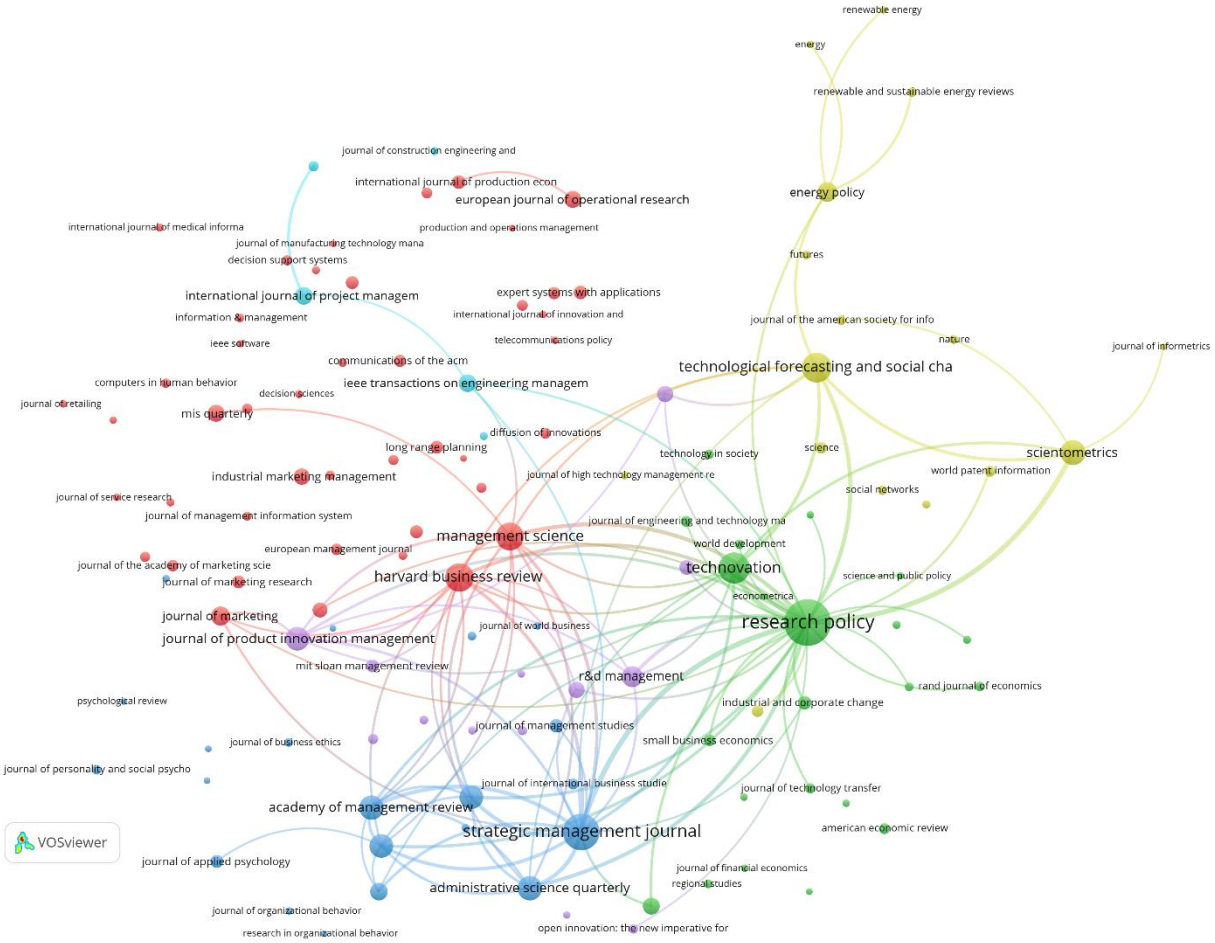


Figure 2. Co-citation of journals during 2009-18: threshold = 50; connections = 100

Research Policy, Technovation, Strategic Management Journal, Technological Forecasting and Social Change, Journal, Harvard Business Review and *Management Science* are the most strongly connected journals to PCMET in the last 10 years. This is not surprising given PICMET's focus on both management and technology.

A steep climb is observed for *Scientometrics* journal, which jumped from rank 12 in 2009-2013 to rank 5 in recent years, providing evidence for an increased focus of PICMET publications on quantitative research methods in recent years. *The Journal of Product Innovation and Management*, on the other hand, had a slight drop from rank 7 (2009-2013) to 11 in recent years. Overall, the analysis confirms PICMET's broad, interdisciplinary publication profile.

Figure 3 visualizes the co-citation of authors of PICMET contributions. Results are shown, again, using a threshold of 50 citations and the 100 most representative connections.

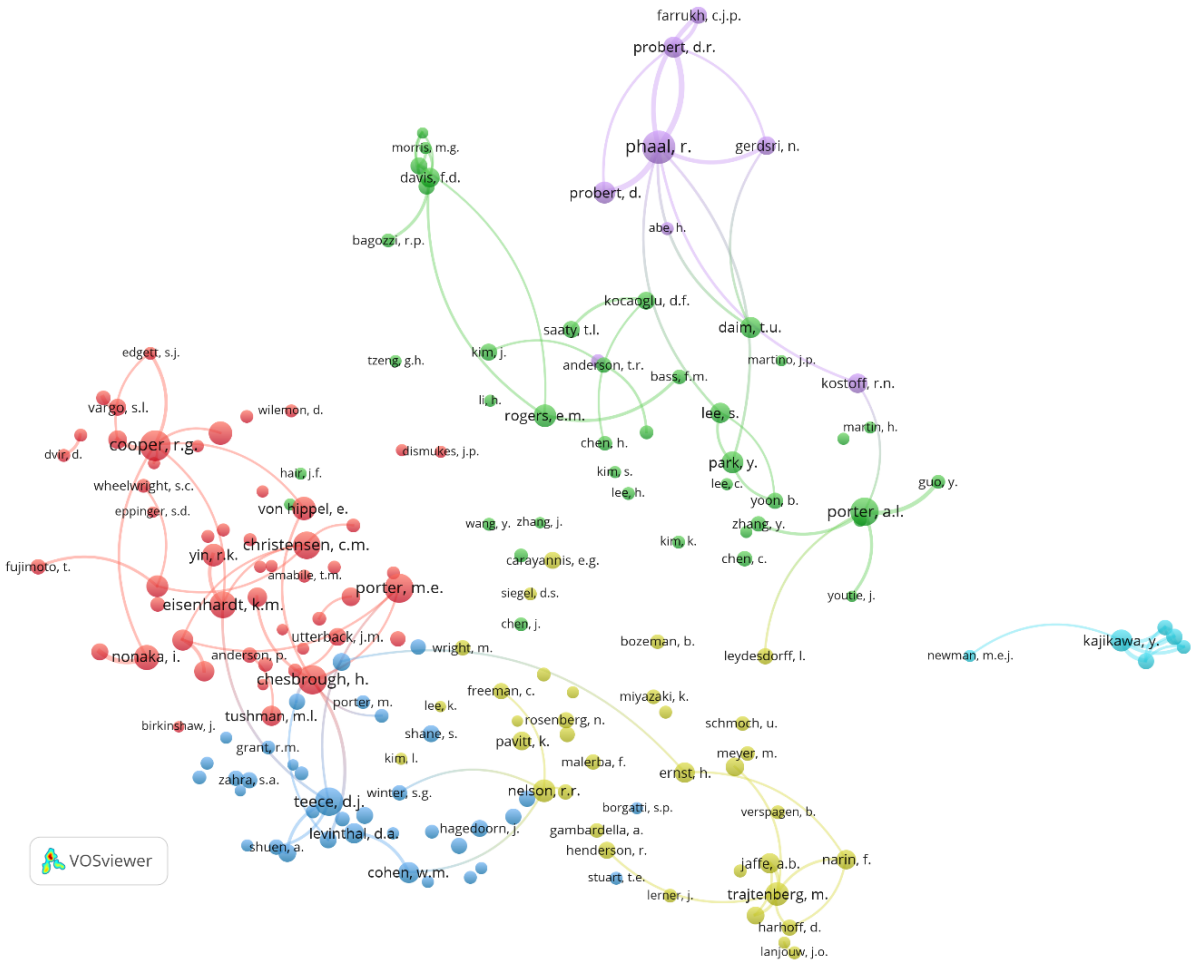


Figure 3. Co-citation of authors: threshold = 50; connections = 100

Results of the co-citation analysis show CM Christensen, ME Porter, H Chesbrough, KM Eisenhardt, RG Cooper, and R Phaal to be among the most co-cited authors in PICMET publications in the last 10 years. R Phaal is also a productive contributor to PICMET, with a total of 30 papers.

5. Discussion and Concluding Remarks

2019 marks the 30th anniversary of PICMET. To celebrate this anniversary, this paper analyzes 20 conferences organized in a 30-year time frame by PICMET. By doing such an analysis, it maps out the evolution of PICMET from the perspective of its contributions to the field of TM. Concentrating on PICMET, offering a conference platform for TM experts, gives us the chance to contribute to TM literature by showing how the representation of the intellectual structure of TM through conference papers could be fruitful to understand the field. It also helps us to

complement the general practice in the literature that mapping is conducted by either journal articles or global databases (such as the studies of Duan, 2011; Cunningham and Kwakkel, 2011; Lee, 2015; Lee and Kang, 2018; Meyer-Brotz et al., 2018).

This paper presents a bibliometric review of PICMET's publications focusing on all 20 conference organized over the period of 1991-2018. Whenever suitable, it compares the findings with the previously conducted PICMET reviews (Porter et al., 2003; Kwakkel et al., 2009) as well as with other existing bibliometric analyses in the TM field. The considerations presented in this paper are based on a broad set of bibliometric indicators and utilize a visualization tool, which allows analysing results by creating a map of bibliographic material. The research focusses on the identification of relevant journals, authors, institutions and countries and aims at offering a comprehensive picture of PICMET's positioning in its academic context.

The results show that PICMET continuously provides a successful platform for academic exchange of ideas in the area of TM. The heavy concentration of PICMET papers on Technology Management, Innovation Management and R&D Management confirms the interdisciplinary nature of TM field as shown by examining journals (Lee, 2015). A slight shift in focus towards more quantitative research methodologies, emerging technologies and economics is in line with wider trends in academic methodology and hot topics in the academic and professional communities.

PICMET, while emphasizing its focus as a platform for the Pacific region, publishes papers from a wide range of institutions in more than 50 countries. The trends show that technology management research is growing in USA, Japan, Germany, China, Taiwan, Korea, South Africa and Brazil among other countries. PICMET has published high quality papers from around 300 participants each year. In sum, the observations of a history of 30-years show that PICMET has become a leading international organization in the Engineering and Technology Management discipline.

This paper focuses on the development of PICMET over a 30-year time frame. It has three limitations that can be opportunities for future research. First, it does not compare conferences organized by other TM associations such as IAMOT and IEEE-TEMS. Future studies can obtain data from these conferences and compare with the evolution of PICMET. Second, the changes that are taking place in the academic research environment are not analyzed. The effect of the

evolution of other TM platforms on PICMET can be studied. Third, research focused on a detailed analysis of PICMET papers cited by journal articles can provide a deeper understanding of the type of conference papers attracting the most significant interest of the wider research community.

Acknowledgments

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

References

T. Allen, 50 years of engineering management through the lens of the IEEE Transactions, IEEE Transactions on Engineering Management 51(4), (2004) 391 395.

D.F. Ball, J. Rigby, Disseminating research in management of technology: journals and authors, R&D Management 36(2), (2006) 205 215.

J. Bar-llan, Informetrics at the beginning of the 21 century- a review, Journal of Informetrics 2(1), (2008) 1 52.

W. Biemans, A. Griffin, R. Moenaert, Twenty years of the journal of product innovation management: history, participants, and knowledge stock and flows, Journal of Product Innovation Management 24(3), (2007) 193 213.

R.N. Broadus, Toward a definition of "Bibliometrics", Scientometrics 12(5-6), (1987) 373 379.

D. Cetindamar, S.N. Wasti, H. Ansal, B. Beyhan, Does technology management research diverge or converge in developing and developed countries?, Technovation 29 (1), (2009) 45 58.

D. Cetindamar, D. Kocaoglu, T. Lammers, J.M. Merigo, A Bibliometric Analysis of Technology Management Research at PICMET for 2009-2018, 2019 Portland International Conference on Management of Engineering and Technology (PICMET), IEEE (2019)

D. Chatterjee, S. Sahasranamam, Technological innovation research in China and India: A bibliometric analysis for the period 1991-2015, Management and Organization Review 14(1), (2018) 179 221.

A. Clausen, I. Wormell, Bibliometric analysis of IOLIM conferences 1977–1999. Journal of Information Science 27(3) (2001) 157 169

M.J. Cobo, A.G. Lopez-Herrera, E. Herrera-Viedma, F. Herrera, Science mapping software tools: Review, analysis and cooperative study among tools, Journal of the American Society for Information Science and Technology 62(7), (2011) 1382 1402.

T. Coupé, Revealed performances: Worldwide rankings of economists and economics departments, 1990–2000, Journal of the European Economic Association 1, (2003) 1309 1345.

S.W. Cunningham, J. Kwakkel, Innovation forecasting: A case study of the management of engineering and technology literature, Technological Forecasting & Social Change 78, (2011) 346 357.

M.C. Di Guardo, K.R. Harrigan, Mapping research on strategic alliances and innovation: a co-citation analysis, Journal of Technlogy Transfer 37, (2012) 789 811.

Y. Ding, R. Rousseau, D. Wolfram, Measuring scholarly impact: Methods and practice. Springer, Switzerland, 2014

C.H. Duan, Mapping the intellectual structure of modern technology management, Technology Analysis & Strategic Management 23(5), (2011) 583 600

B. Durisin, G. Calabretta, V. Parmeggiani, The intellectual structure of product innovation research: A bibliometric study of the Journal of Product Innovation Management, 1984–2004, Journal of Product Innovation Management 27, (2010) 437 451.

J. Fagerberg, M. Fosaas, K. Sapprasert, Innovation: Exploring the knowledge base, Research Policy 41(7) (2012) 1132 1153.

M.T. García-Merino, M.L. Pereira-do-Carmo, M.V. Santos-Álvarez, 25 years of Technovation: Characterisation and evolution of the journal, Technovation 26(12), (2006) 1303 1316.

M. Gaviria-Marín, J.M. Merigó, S. Popa, Twenty years of the Journal of Knowledge Management: A bibliometric analysis, Journal of Knowledge Management 22, (2018) 1655 1687.

A.E. Gudanowska, A map of current research trends within technology management in the light of selected literature, Management and Production Engineering Review 8 (1) (2017) 78 88.

A.C. Inkpen, P.W. Beamish, An analysis of twenty-five years of research in the Journal of International Business Studies, Journal of International Business Studies 25, (1994) 703 713.

M.M. Kessler, Bibliographic coupling between scientific papers, American Documentation 14(1), (1963) 10 25.

A. King, Concerning conferences, Journal of Documentation 17(2) (1961) 69 76.

D. Kocaoglu, Technology and innovation management, PICMET ‘99. Portland, OR, 24-29 July (1999).

J. Kwakkel, S.W. Cunningham, T.R. Anderson, Remining PICMET, PICMET ’09, Portland, OR, 2 – 6 August (2009)

H. Landström, G. Harirchi, F. Aström, Entrepreneurship: exploring the knowledge base, Research Policy 41, (2012) 1154 81.

H. Lee, Uncovering the multidisciplinary nature of technology management: journal citation network analysis, Scientometrics 102, (2015) 51 75.

H. Lee, P. Kang, Identifying core topics in technology and innovation management studies: a topic model approach, Journal of Technology Transfer 43 (2018) 1291–1317.

J.D. Linton, Perspective: Ranking business schools on the management of technology, Journal of Product Innovation Management 21, (2004) 416 430.

J.D. Linton, N. Thongpapanl, Perspective: Ranking the technology innovation management journals, Journal of Product Innovation Management 21 (2004) 123 139.

J.M. Merigó, A. Mas-Tur, N. Roig-Tierno, D. Ribeiro-Soriano, A bibliometric overview of the Journal of Business Research between 1973 and 2014, Journal of Business Research 68(12), (2015) 2645 2653.

F. Meyer-Brotz, B. Stelzer, E. Schiebel, L. Brecht, Mapping the technology and innovation management literature using hybrid bibliometric networks, International Journal of Technology Management 77(4), (2018) 235 286.

A. Pilkington, Technology management: A comprehensive bibliometric analysis, IEEE International Technology Management Conference, Chicago, IL, 12-15 June (2014).

P.M. Podsakoff, S.B. MacKenzie, N.P. Podsakoff, D.G. Bachrach, Scholarly influence in the field of management: a bibliometric analysis of the determinants of university and author

impact in the management literature in the past quarter century, Journal of Management 34, (2008) 641 720.

A.L. Porter, R.J. Watts, T.R. Anderson, Mining PICMET: 1997-2003 papers help you track management of technology developments, PICMET ‘03. Portland, OR, 20-4 July (2003).

A.L. Porter, D.J. Schoeneck, T.R. Anderson, PICMET Empirically: Tracking 14 Management of Technology Topics, PICMET ‘12. Vancouver, Canada, July 29 - August 2 (2012).

S. Sarin, C. Haon, M. Belkhouja, A bibliometric analysis of the knowledge exchange patterns between major technology and innovation management journals (1999-2013), Journal of Product Innovation Management 35(1) (2018) 2 8.

V. Shum, A. Park, E. Maine, L.F. Pitt, A Bibliometric Study of Research-Technology Management, 1998-2017, Research-Technology Management 62, (1) (2019) 34 43.

H. Small, Co-citation in the scientific literature: A new measure of the relationship between two documents, Journal of the American Society for Information Science 24, (1973) 265 269.

J. Thieme, Perspective; The world’s top innovation management scholars and their social capital, Journal of Product Innovation Management 24, (2007) 214 229.

N.T. Thongpapanl, The changing landscape of technology and innovation management: An updated ranking of journals in the field, Technovation 32, (2012) 257 271.

N.J. Van Eck, L. Waltman, Software survey: VOSviewer, a computer program for bibliometric mapping, Scientometrics 84(2), (2010) 523 538.

P. Yang, L. Tao, Perspective: Ranking of the world’s top innovation management scholars and universities, Journal of Product Innovation Management 29(2), (2012) 319 331.